

*Annual Performance Report*

**Particle Astrophysics and Cosmology**

(NAG 5-2788)

Fermi National Accelerator Laboratory

P.O. Box 500 Batavia, Illinois 60510-0500

For the period 15 November 1994 (start date of new grant) — 15 September 1995

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The Theoretical Astrophysics Group at Fermilab is a center for research on the connections between particle physics, early-universe physics, and the present universe.

In the ten-month period November 1994 to September 1995 the group produced 39 scientific publications on a wide variety of topics. It is impossible in this brief report to highlight the results of each individual investigation, so papers will be grouped into subject areas.

- Big-bang nucleosynthesis: Several investigations continued the Chicago/Fermilab tradition of leading-edge research in this important topic. In addition to refining the calculation of the primordial elements, we have focused much recent effort on the early chemical evolution of the light elements.
- Dark matter in our galactic halo: The discovery of microlensing of stars in the LMC and toward the galactic bulge forced a reconsideration of the composition of the dark matter component of our galaxy. A particular emphasis of our group is the interpretation of the microlensing results for the existence of a non-baryonic dark matter component of the galaxy. We also studied the phase-space structure of the particle dark matter component.
- Dark matter candidates: Our work this year concentrated on three candidates to account for the discrepancy between the expected value of the cosmic density and the amount that can be accounted for in terms of baryons: axions, photinos, and a cosmological constant.
- Primordial magnetic fields: The origin, evolution, and astrophysical implications of primordial magnetic fields may be important for structure formation and cosmic rays. Our group is starting an active research effort in this field.
- CMB fluctuations: Fluctuations in the temperature of the cosmic microwave background radiation is a direct probe of conditions in the universe at the time of recom-

bination (about 300,000 years after the bang). It is also a powerful indirect probe of conditions in the universe at *much* earlier times. Our group is particularly interested in what the CMB fluctuations can tell us about the physical processes that led to the fluctuations, and in reverse, what information the theories tell us to look for in the fluctuations..

- Inflation: Fifteen years after its proposal, the idea of an inflationary epoch in the early universe continues to be an important part of early-universe cosmology. In addition to the traditional role of our group in model building, we have focused on some phenomenological issues in the implications of specific models for CMB fluctuations and structure formation. We have also pioneered the idea that from astronomical observations we might be able to piece together information about the inflationary potential.
- Large-scale structure: As the field looks forward to the next generation of large-scale structure surveys such as the Sloan Digital Sky Survey, our group has been involved in several issues in structure formation. From testing warm dark matter models, to studying self-similarity and scaling behavior of scale-free gravitational clustering, and effects of sampling on measuring galaxy count probabilities, we continue to work in conjunction with the Fermilab observational program.

In addition to scientific work listed in the publications, there is an intangible quality of scientific leadership. Through our visitor program, work by staff members organizing conferences like the 1994 Snowmass Summer Study and the upcoming 1996 Texas Symposium to be held in Chicago, lectures by senior group members at conferences and summer schools, public outreach activities, and other efforts that do not show up in the publication list, we feel that our group continues to play an important role in early-Universe astrophysics.

**Fermi National Accelerator Laboratory  
Theoretical Astrophysics**

**Publications List - November 1994 to September 1995**

<b><u>Pub</u></b>	<b><u>Title</u></b>	<b><u>Date</u></b>
94/381-A	E. Gates, G. Gyuk and M.S. Turner "Microlensing and Halo Cold Dark Matter" <i>Phys. Rev. Lett.</i> , <b>74</b> , 3724-3727 (1995)	Nov. 1994
94/387-A	P. Bhattacharjee and G. Sigl "Monopole Annihilation and Highest Energy Cosmic Rays" <i>Phy. Rev. D</i> , <b>51</b> , 4079-4091 (1995)	Nov. 1994
94/390-A	B. D. Fields "On the Evolution of the Light Elements: I. D, $^3\text{He}$ , and $^4\text{He}$ " (Submitted to <i>ApJ</i> )	Nov. 1994
94/428-A	E. Kim, A. Olinto, and R. Rosner "Generation of Density Perturbations by Primordial Magnetic Fields"	Dec. 1994
95/008-A	L. Knox "Determination of Inflationary Observables by CMB Anisotropy Experiments" (Submitted to <i>Phys. Rev. D</i> )	Jan. 1995
95/013-A	Y. Wang "Simple Analytical Methods for Computing the Gravity-wave Contribution to the Cosmic Background Radiation Anisotropy" (Submitted to <i>Phys. Rev. D</i> )	Jan. 1995
95/021-A	M. Gleiser, etal "Oscillons: Resonant Configurations during Bubble Collapse" <i>Phys. Rev. D</i> <b>52</b> : 1920-1933, 1995	Feb. 1995
Conf. 95/034-A	M. S. Turner "The Hot Big Bang and Beyond" (To be published in the <i>Proceedings of CAM-94</i> , Cancun, Mexico- Sept. '94, and the <i>Proceedings of Diffuse Background Radiation</i> - <i>IAU 168</i> , The Hague, August 15-27, 1994)	Mar. 1995

95/051-A	G. Sigl, K. Jedamzik, D.N. Schramm and V.S. Berezinsky "Helium Photodisintegration and Nucleosynthesis: Implications for Topological Defects, High Energy Cosmic Rays, and Massive Black Holes" (Submitted to <i>Phys. Rev. D</i> )	Mar. 1995
95/059-A	A. F. Heckler "Hot Black Holes from Photosphere" (To be submitted to <i>Phys. Rev. D</i> )	Mar. 1995
95/063-A	L. M. Krauss & M. S. Turner "The Cosmological Constant is Back" (Submitted to <i>General Relativity &amp; Gravitation</i> )	Mar. 1995
95/066-A	J. Frieman, C.T. Hill, A. Stebbins, and I. Waga "Cosmology with Ultra-high Pseudo-Nambu-Goldstone Bosons" (Submitted to <i>Phys. Rev. Letts.</i> )	Apr. 1995
95/068-A	G. R. Farrar and E. W. Kolb "Light Photinos as Dark Matter" (Submitted to <i>Phys. Rev. D</i> )	Apr. 1995
95/070-A	C. Copi and D. N. Schramm "The Nuclear Impact on Cosmology: The $H_0$ - $\Omega$ Diagram" (Submitted to <i>Comments on Nuclear and Particle Physics</i> )	Apr. 1995
95/071-A	A. Kosowsky and M. S. Turner "CBR Anisotropy and the Running of the Spectral Index" <i>Phys. Rev. D</i> <b>52</b> : 1739-1743, 1995	Apr. 1995
95/074-A	M. Abney and R. I. Epstein "Ekman Pumping in Astrophysical Bodes" (To be submitted to the <i>Journal of Fluid Mechanics</i> )	Apr. 1995
95/080-A	P. Sikivie, I. Tkachev and Y. Wang "The Velocity Peaks in the Cold Dark Matter Spectrum on Earth" (Accepted for publication in <i>Phys. Rev. Letts.</i> )	Apr. 1995
95/090-A	E. Gates, G. Gyuk and M. S. Turner "The Local Halo Density" (Submitted to <i>ApJ Letts.</i> )	Apr. 1995
95/091-A	L.F. Bloomfield Torres and I. Waga ""Decaying $\Lambda$ Cosmologies and Statistical Properties of Gravitational Lenses"	Apr. 1995

- 95/093-A S. Colombi, S. Dodelson and L. W. Widrow May 1995  
 "Large Scale Structure Tests of Warm Dark Matter"  
 (Submitted to *ApJ*)
- Conf  
 95/125-A M. S. Turner May 1995  
 "The Hot Big Bang and Beyond"  
 (Conference on "*Galaxies in the Young Universe*"-  
 Tegernsee, Germany, Sept. 1994)
- Conf  
 95/126-A M. S. Turner May 1995  
 "Inflation: From Theory to Observation and Back"  
 Conference - *17th Texas Symposium on Relativistic Astrophysics-*  
*- Munich, Germany, December 1994*
- 95/134-A N. Terasawa and M. Hattori May 1995  
 "Effect of Kick Velocity on the Gamma-ray Burster Distribution"
- 95/140-A C. J. Copi, D. N. Schramm and M. S. Turner June 1995  
 "Big-Bang Nucleosynthesis and Galactic Chemical Evolution"  
 (Submitted to *ApJ Letts.*)
- 95/148-A G. Sigl, S. Lee, D.N. Schramm, and P.B. Bhattacharjee June 1995  
 "A Break in the Highest Energy Cosmic Ray Spectrum:  
 A Signature of New Physics?"  
 (Submitted to *Science*)
- Conf  
 95/151-A J. A. Frieman June 1995  
 "Cosmological Models at the Millennium"  
 (To appear in "*Particle and Nuclear Astrophysics & Cosmology*  
*in the Next Millennium*", *Proceedings of 1994 DPF Summer Study*  
*on High Energy Physics, Snowmass, CO 29-Jun - 14 Jul, 1994*,  
 eds. E. Kolb and R. Peccei, Singapore: World Scientific)
- 95/157-A J. Ellis, B. Fields and D.N. Schramm June 1995  
 "Geological Isotope Anomalies as Signatures of Nearby Supernovae"  
 (Submitted to *ApJ*)
- 95/220-A D. V. Semikoz and I. I. Tkachev July 1995  
 "Condensation of Bosons in Kinetic Regime"
- 95/256-A S. Colombi, F.R. Bouchet and L. Hernquist July 1995  
 "Self-similarity and Scaling Behavior of Scale-Free Gravitational  
 Clustering"  
 (Submitted to *ApJ*)

- 95/257-A C.J. Copi, D.N. Schramm and M.S. Turner July 1995  
 "Assessing Big Bang Nucleosynthesis"  
 (Submitted to *Phys. Rev. Letts.*)
- Conf  
 95/261 -A J. A. Frieman August 1995  
 "The Cosmological Constant: Plus ca Change, plus C'est la meme chose"  
 (To appear in the *Proceedings of the 3rd Colloque Cosmologie*,  
 eds. H.J. deVega and N. Sanchez: World Scientific)
- 95/266-A I. Szapudi and A.S. Szalay August 1995  
 "Effects of Sampling on Measuring Galaxy Count Probabilities"  
 (Accepted by *ApJ*)
- 95/267-A E. Gates, G. Gyuk, and M.S. Turner August 1995  
 "Gravitational Microlensing and the Galactic Halo"  
 (Submitted to *Phys. Rev. D*)
- 95/272-A Y. Wang and E.L. Turner August 1995  
 "Statistics of Extreme Gravitational Lensing Events"
- Conf.  
 95/273-A Y. Wang August 1995  
 "The Statistics of Nearly On-Axis Gravitational Lensing Events"  
 To appear in the *Proceedings of IAU Symposium 173: Astrophysical  
 Applications of Gravitational Lensing - University of Melbourne,  
 Australia, July 9-14, 1995*
- 95/174-A G. Sigl August 1995  
 "Weak Interaction in Supernova Cores and Saturation of Nucleon  
 Spin Fluctuations"  
 (Submitted to *Phys. Rev. Letts.*)
- 95/280-A J. E. Lidsey, A. Liddle, E.W. Kolb, etal August 1995  
 "Reconstructing the Inflaton Potential -- An Overview"  
 (To be submitted to *Review of Modern Physics*)
- 95/282-A S. Lee, A. Olinto and G. Sigl August 1995  
 "Extragalactic Magnetic Field and the Highest Energy Cosmic Rays"  
 (Submitted to *ApJ Letts.*)
- 95/294-A J.A. Frieman and R. Scoccimarro September 1995  
 "Loop Corrections in Non-Linear Cosmological Perturbations"  
 (To be submitted to *ApJ*)

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